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The drift chamber for the experiment to study the nature of the confinement

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Abstract

The GlueX experiment was designed to search for hybrid mesons with exotic quantum numbers using a beam of linearly polarized photons incident on a liquid hydrogen target. The spectrum of these states and their mass splitting from normal mesons may yield information on confinement. The description of the GlueX spectrometer and Forward Drift Chambers (FDC) as a part of track reconstruction system is presented in the text. FDC`s are multiwire chambers with cathode and anode read-out. The system allows reconstructing tracks of charged particles with ~200mkm accuracy with angles from 20˚up to 1˚. One of the detector features is 1.64% X_0 material amount in the active area. The cathode gain calibration procedure is presented. The results of such calibration using cosmic data and beam data are presented as well.

*Keywords:*Detectors; GlueX experiment;Confinement;Drift chambers;Cathode readout

1. Introduction

Understanding of the quarks and gluons confinement in quantum chromodynamics (QCD) is one of the fundamental challenges in modern physics. Confinement is a unique property of QCD and understanding confinement requires an understanding the soft gluonic field responsible for binding quarks in hadrons. Hybrid mesons, and in particular exotic hybrid mesons, provide the ideal laboratory for testing QCD in the confinement

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regime since these mesons explicitly manifest the gluonic degrees of freedom. Photoproductionis expected to be particularly effective in producing exotic hybrids but there is a little data on the photoproduction of light mesons. Hybrid mesons decays are expected to provide several particles in the final state, mostly charged pions and photons. The meson spectroscopy based on the Partial Wave Analysis (PWA) requires a nearly-hermetic detector for these secondary particles [1].

The GlueX experiment will use the coherent bremsstrahlung technique to produce a linearly polarizedphoton beam. In order to reach the ideal photon energy of 9 GeV for this mapping of the exotic spectrum, 12 GeV electrons are required. Linearly polarized photon beam will interact with liquid hydrogen target located inside of a superconductive solenoid bore.

A solenoid-based hermetic detector will be used to collect data on meson production and decays with statistics exceeding the current photoproduction data in hand by several orders of magnitude after the first year of running [2]. The spectrometer has been optimized for experiment GlueX with the primary goal to search for new exotic meson states. The photoproduction data will also be used to study the spectrum of conventional mesons, including the poorly understood excited vector mesons and strangeonium.

2. The GlueX spectrometer

The principal scheme of high acceptance GlueX spectrometer is shown in Fig. 1. The start counter device surrounds liquid hydrogen target. This detector consists of plastic scintillator pads and provides time information of events. In order to reconstruct exotic meson decay events, accurate reconstruction of the incident photon, as well as the produced charge particles and photons is necessary.

In order to reconstruct π° and η mesons, the GlueX detector must detect and reconstruct photons. A pair of calorimeters carries this out. The barrel calorimeter is located inside the bore of the magnet with 2 Tesla field and forward calorimeter located after the solenoid downstream of the time-of-flight wall. Two types of drift chambers are installed inside the barrel calorimeter. The tracking drift chambers are designed to reconstruct the momenta of the charged particles emerging from the target. The straw type central drift chambers (CDC) cover target and reconstruct charge tracks with angles from 20˚ to 150˚, which provides very good $r - \varphi$ and good z resolution. In addition, this detector provides some dE/dx information to aid in the separation of pions, kaons and protons up to momenta of about 0.45 GeV/c – a regime where dE/dx measurements work extremely well. The Forward Drift Chambers (FDC) are multiwire chambers with anode and cathode read-out designed to measure tracks of charged particles coming from hydrogen target in the forward direction with angles up to 20˚. The main properties of this gaseous device will be listed and described below.

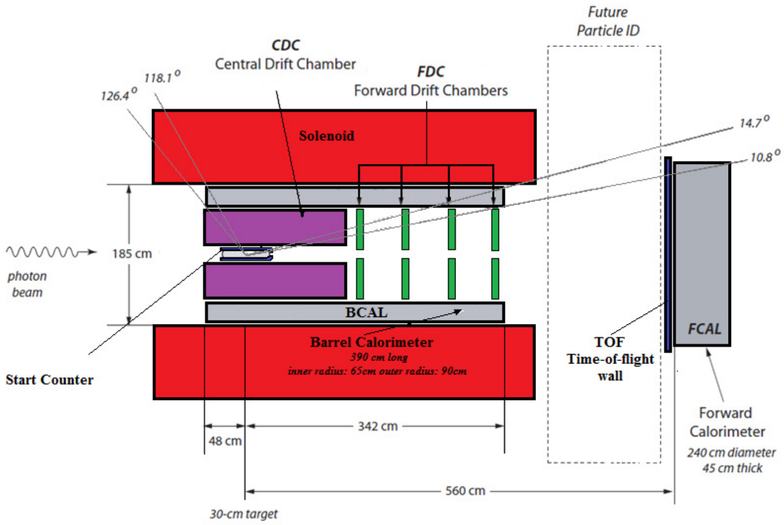

Fig. 1. A schematic view of the GlueX spectrometer.

3. The Forward Drift Chambers

The Forward Drift Chambers system consists of twenty-four independent similar drift chambers divided in four separate identical packages. Each package is installed in different positions from target perpendicular to the photon beam line. Basically, a package is six drift detectors or planes is closely spaced to each other. Each plane is rotated to 60 degree with respect to other. The photo of such detector before installation inside the magnet bore is shown in Fig. 2.

Fig. 2. The photo of assembled Forward Drift Chambers (FDC) detector.

Each drift chamber consists of three layers. Anode wire plane is located between two cathodes planes, which are rotated to ±75° with respect to the wires. The gas space between cathode and wire plane is 5 mm.

Wire plane has 96 signal gold-plated tungsten wires alternated with 97 gold-plated Cu-Be field wires. Their diameter is 20mkm and 80mkm for signal and field wires, respectively. The space between two type of wires is 5mm.The positive voltage applied to sense wires provides the gain around $5x10^4$. On the other hand, the negative voltage provides circular symmetry of electric field.

The cathode plane is made in the form of 216 thin (~2mkm) copper strips with different lengths printed at capton film (~25 mkm). The film is glued to holding frame of cathode layer. The width of each strip is 4 mm. Each strip ends with very thin traces used to read-out strips. The traces are connected to preamp connector using anisotropic conductive film. A process of such connection is a very delicate operation and the soldering technology is unacceptable [3].

All this design features were made to provide good pattern recognition. The pattern recognition is an important part of the track reconstruction. Track reconstruction algorithm requires finding local clusters of hits associating them into small track segments. These track segments can be combined into larger tracks.

The FDC provides 3-dimensional points. It uses the drift timing information from the wires and analogue signals from the cathodes allowing working in high rate conditions. In addition to this requirement, the detector has minimum amount of material in active area and periphery. The active material affects the momentum resolution of the charged particles and photons reconstruction by barrel calorimeter in large magnetic field conditions. The amount of material in the active area of all FDC system is ~1.64% X_0.

4. The cathode strips gain calibration

There is a variance in FDC`s cathode gains. It can be explained by the differences in front-end preamplifier gains, readout cables and digitizer input. On the other hand, the anisotropic conductive film technology has problems when some stress is applied to connection area. This translates into “missing” channel problem because traces lose connection to the preamp cards. All these issues lead to a cathode strips gain calibration requirement.

In total 10368 cathode strips in 24 chambers should be calibrated. The main idea of the calibration procedure is explained as follows. A charge from an avalanche distributed at upper and bottom strips should be the identical because of the chamber geometry. But this is not enough for coefficients calculation. Another statement is added to make this procedure work. Distributed charge value in the centre of the strip point is determined by Matheson function [4].

Matheson fit function value in a point representing the centre of the strip should be equivalent to the amplitude read-out from this strip. The sum of these statements should be minimal for all events. The formula presented below describes these statements.

$$\sum_{events}\left\{\left(\sum_{i=1}^{216}\left(C_i * A_i\right)-\sum_{j=1}^{216}\left(C_j * A_j\right)\right)^2+\sum_{l=1}^{432}\left(f(l)-C_l * A_l\right)^2\right\}\rightarrow \min \tag{1}$$

Where:

- C_i – upper strip coefficient, and index is a strip number,
- A_i – amplitude read-out from the upper strip,
- C_j – bottom strip coefficient, and index is a strip number,
- A_j – amplitude read-out from the bottom strip,
- (l) - fit function value in the centre of the strip; l≤216 upper strips; l>216 bottom strips.

Two cosmic dataplots are shown in Fig. 3. One of them is a result of calibration coefficients calculations versus strip number. The second one demonstrates hit occupancy versus strip number. Shape of occupancy distribution can be explained by the fact that the central strips are longer. These plots were made for one of the chambers. The strong correlation between bad channels and big coefficients is obvious and it is observed on the plots.

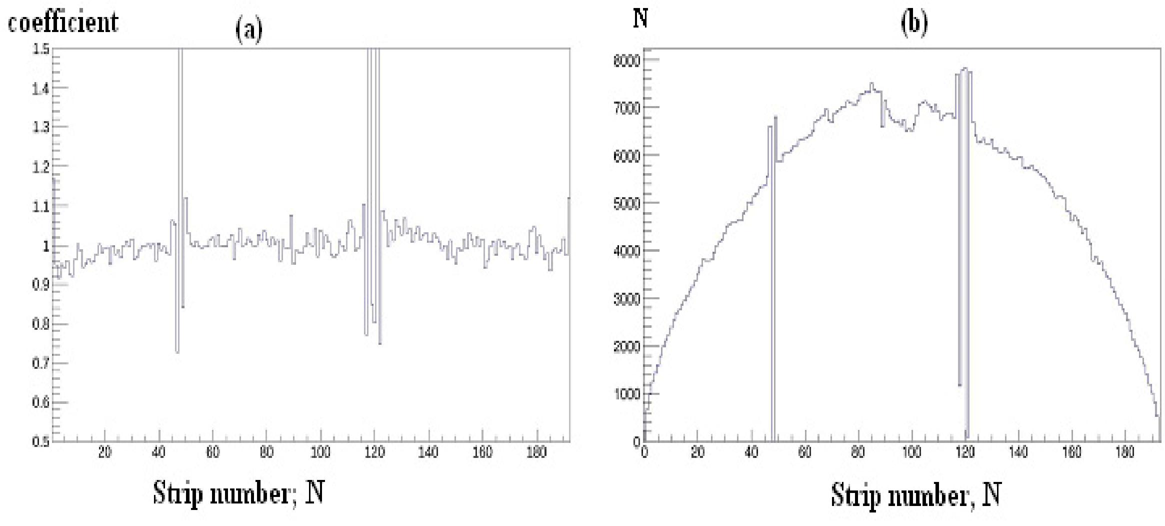

Fig. 3. a) Calculated coefficients versus strip number for cosmic data. b) Hit occupancy versus strip number for the same cosmic run.

The strips have been calibrated using beam data from 2014 fall commissioning run at the TJNAF CEBAF machine. Electrons with 10.1GeV energy pass through aluminium radiator at tagger hall, and photons transfer to experimental hall D and interact with plastic target. During the data taking, the magnet field was turned off and the trigger type was optimized to provide good hit occupancy in all working areas of forward drift chambers for the calibration procedure. The results of this calibration for one of the chambers are shown in Fig. 4.

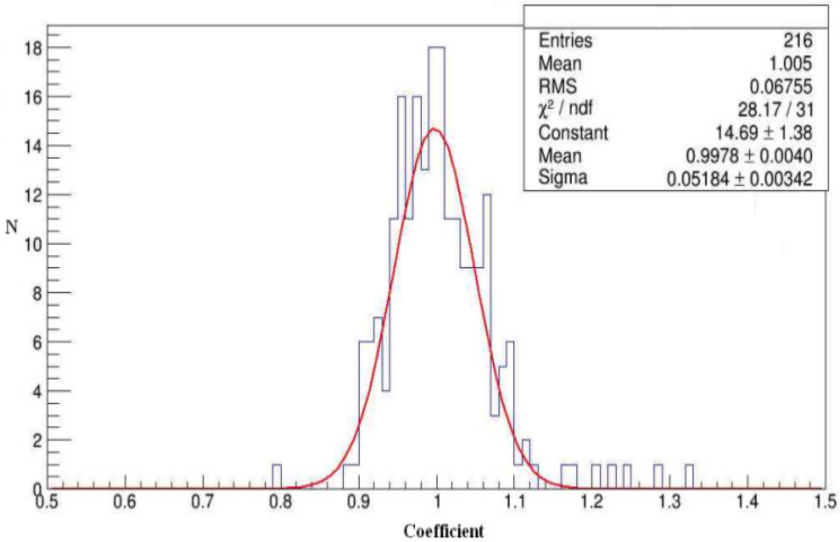

Fig.4. Distribution of cathode gain coefficients calculated from the beam data.

As obviously visible from the results, the gain coefficient distribution is about 8-9%. This amount is not that big. This result gives an indication that the system was assembled, installed and connected with high accuracy and electronics part performs great as well.

5. Outlook

The Forward Drift Chambers was assembled, connected and installed inside the superconductive solenoid. This detector showed high efficiency during the 2014 beam run. The performance of detector demonstrated that it can reconstruct 3D space points with ~200mkm spatial resolution. The cathode strip calibration was made using cosmic and beam data. The constants were downloaded into the calibration database. Track reconstruction algorithms will use these constants, which automatically improves the efficiency of charged track determination and reconstruction during future physics data taking runs.

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